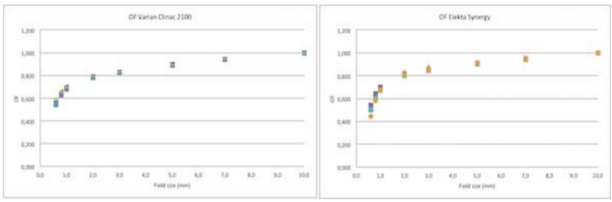

Fig. 1. OF values measured with W1 PSD for the two most representative linacs of the multicenter study

Conclusion: High TPR and penumbra values consistency were obrained over the centers. FWHM and OF showed greater variability, also considering Linac with the same model of the head. Measurements confirm W1 PSD as a good candidate for small field clinical radiation dosimetry in advanced radiation therapy techniques.

PO-0819

Analysis of liquid embolic agents on flattening filter free dose deposition with Monte Carlo method

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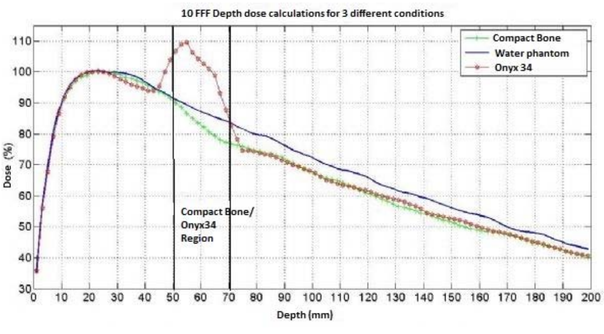
Purpose or Objective: Brain Arteriovenous mal-formation (AVM), in some cases, is treated with Onyx34 liquid embolic system (LES) containing tantalum. Moreover, stereotactic radiosurgery (SRS) may be required when total obliteration is not achieved after embolization. Presence of tantalum in radiation field not only generates artefacts in computed tomography (CT) images but also it could arise dose distribution perturbations. Goal in this study was to analyze the perturbation effect of Onyx34 in flattening filter free (FFF) photon beams using GAMOS Monte Carlo (MC). Artefact cause analysis was also included in the study.

Material and Methods: GAMOS simulations for 6 FFF and 10 FFF photons were done in three different conditions: a) depth dose simulations in a water phantom containing 2x2x2 cm3 Onyx34 (inc. %35wt/vol Ta) medium at 5 cm depth, b) depth dose simulations in the same condition with compact bone instead of Onyx34, c) simulations in homogenous water phantom. Dose and photon flux scorers were used at central beam axis with 5x5x2 mm3 grid sizes. For comparison purposes, photon fluxes were also scored with broad photon beam with single photon energy of 80 keV. All of MC calculations were done with 1.5% and 0.5% statistical noise respectively.

Results: In 80 keV photon simulations, photon flux decreased around 50% at post Onyx34 region relative to homogeneous water simulations. However, for compact bone falloff was around 10% at the same geometry. Also, there was a remarkable flux reduction in pre-Onyx34 region which is not as much as post Onyx34 region. For both 6 and 10 FFF photon beams, around 5% of decrease was seen in photon flux and depth dose after Onyx34 and compact bone inhomogeneties . Pre-Onyx34 region doses were increased by 15% for 6 FFF and 10% for 10 FFF.



Conclusion: Photon flux calculations for 80 keV beam, showed a considerable photon attenuation and lateral scattering due to presence of Onyx34. As a result, photon starvation causes black-white streak artefacts in CT images. In conclusion, in AVM SRS planning the presence of LES can be taken into account by defining high density artefact region as a compact bone. However in vicinity of critical structures, the possible dose peaks must be considered at pre-Onyx regions which might not be calculated in treatment planning systems.

PO-0820

Volumetric quality assurance of RapidArc plans for multiple intracranial targets using gel dosimetry

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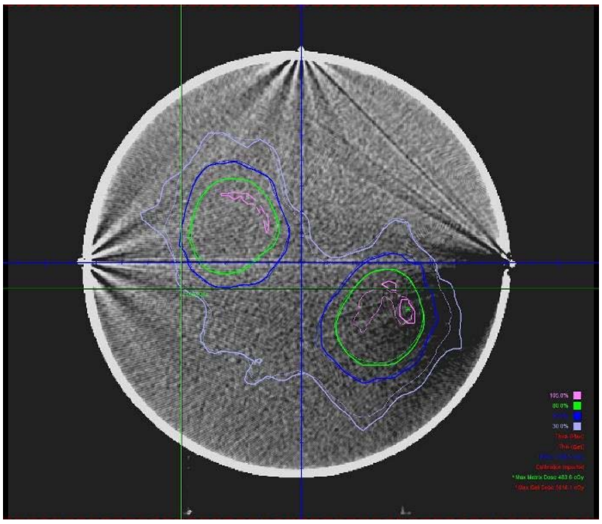
Purpose or Objective: Given the unlimited spatial arrangements of multiple intracranial tumors, an evaluation of a planar sampling for end-to-end test is insufficient as it could provide no information about one or more tumors. Hence, a volumetric approach is needed. Here, we evaluate polymer gel dosimetry for three-dimensional (3D) patient-specific quality assurance (QA) in multiple brain lesions stereotactic radiosurgery (SRS) plans using volumetric modulated arc therapy (VMAT) technique.

Material and Methods: End-to-end test using polymer gel dosimeters was performed for an intracranial SRS case involving two lesions treated with VMAT – single isocenter approach. The following was performed: (1) BANG-3 polymer gel was prepared for two opaque spherical glass phantoms, one for patient plan QA and one for calibration; (2) the patient plan was delivered to the patient phantom and a simple non-modulated plan with predetermined doses was given to the calibration phantom; (3) 1.5T MRI was performed on both phantoms; (4) an in-house program was used to determine the relaxation rate maps (R2) from proton density and T2-weighted images; (5) CT scans were acquired with markers triangulating the isocenter of irradiation setups; (6) CTs were imported into Eclipse treatment planning system for dose computation in corresponding gel phantoms; (7) CTs and MRs were registered in Eclipse and registration transformations used to resample the R2 maps in corresponding CT positions using MATLAB. Then, data analysis was performed using an in-house visual-C++ code which took as input all 3D images, 3D dose, patients' structures exported from Eclipse and performed the following: (8) A calibration was extracted from the calibration gel and used in the patient gel QA; (9) the patients' structures were registered with the patients' gel using CT isocenter marks on the gel phantom and through the isocenter on the patients' plan; and (10) compared measured versus planned 3D isodose, dose volume histogram (DVH) analyses, and multi-slice 2D gamma evaluation.

Results: The measured isodose lines and surfaces were well visualized and qualitatively reproduced the calculated dose distribution (Figure 1). Gamma analysis between the dose matrices were carried out using gamma criteria 3% 3mm and 5% 5mm, % dose difference – distance to agreement combination within the volume enclosed by the 50% and the 80% isodose surface, respectively. Representative transverse slices yielded gamma pass rates of greater than 90%. Measured and planned DVH analyses showed agreement for planning target volume and organs at risk.



Conclusion: Polymer gel dosimetry shows promise for volumetric patient-specific QA of IMRS dose distributions. It does not present limitations when treatments involve couch rotation and gives a complete 3D assurance. However, it is labor intensive to be applicable in daily clinical practice. Nevertheless, the gel method has an important role during safe implementation of a SRS program.

PO-0821

A comparison between different patient QA devices for IMRT treatments on VERO system

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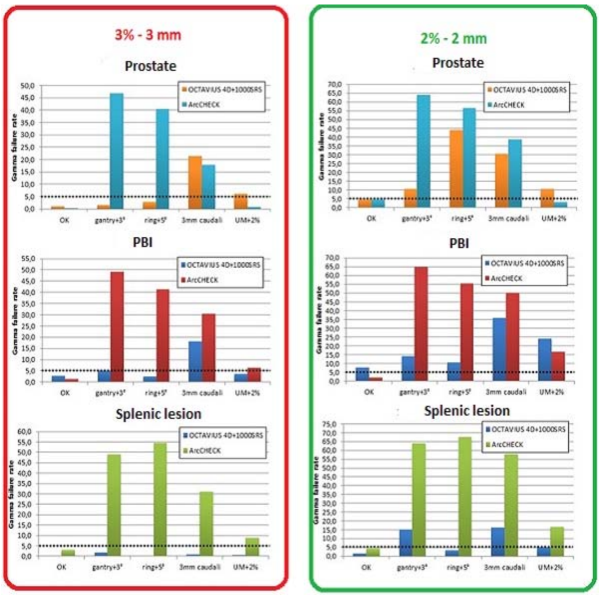
Purpose or Objective: The purpose of this study was to compare the ability of OCTAVIUS® 4D phantom with 1000 SRS array (PTW) and ArcCHECK® system (SunNuclear) in detecting geometric and dosimetric errors intentionally introduced into the IMRT step-and-shoot treatments delivered with VERO® system (Mitsubishi Heavy Industries and BrainLAB). Moreover, the impact of these errors on the DVH of PTVs and OARs was investigated.

Material and Methods: The treatment plans of 3 clinical cases were considered (prostate, partial breast irradiation PBI and splenic lesion). From each of the original plans, 4 verification plans were created, containing one intentional error per plan: gantry rotation of +3°, ring rotation of +5°, 2% increased number of monitor units and isocenter translation of 3 mm (caudal direction). All the plans were calculated with iPlan 4.5.3 (BrainLAB) with a calculation grid of 2 mm on a mathematical phantom, for OCTAVIUS® 4D system, and on the CT images (plug inserted), for ArcCHECK®. The analysis was executed applying the 3D γ evaluation method (3% local dose-3mm and 2% local dose-2mm, 10% dose threshold), comparing the original calculated distributions with the measured ones (with errors) using the related software (VeriSoft® Patient Plan Verification Software for OCTAVIUS 4D®, coronal projection, and SNC Patient™ Software for ArcCHECK®). The tolerance level considered was 5% for the gamma failure rate (an error was considered detected when the gamma failure rate was higher than 5%). The impact of the errors introduced was evaluated by considering the DVH of PTVs (D98%, D2% and Dmean), rectum (D50% and D5%), ipsilateral lung (D40% and D10%) and spinal cord PRV (Dmax) respectively. The Pearson's correlation coefficient between the variation of the gamma passing rate and the variations of the DVHs points for the PTVs and the OARs considered was also calculated.

Results: The results of the 3D γ evaluation are reported in the figure, both for 3%-3 mm and 2%-2 mm criteria, for the original plans and for the modified ones. Using McNemar's test, the total detection rate detected by ArcCHECK® was higher than that of OCTAVIUS® 4D (p= 0.045), with 3%-3 mm criteria, while it was comparable with 2%-2 mm criteria (p= 0.480).



The Pearson's correlation coefficient calculated between the variation of the gamma passing rate and the variations of the constraints for the OARs considered are shown in the table.

OCTAVIUS® 4D + PTW 1000SRS

r					
	PTV			OAR	
Prostate	$D_{98\%}$	$D_{2\%}$	D_{mean}	Rectum $D_{50\%}$	Rectum $D_{5\%}$
3%-3 mm	**0.848**	0.236	0.408	-0.689	**-0.994**
2%-2 mm	0.587	-0.170	0.019	**-0.840**	**-0.936**
PBI	$D_{98\%}$	$D_{2\%}$	D_{mean}	Lung $D_{40\%}$	Lung $D_{10\%}$
3%-3 mm	**0.899**	0.543	0.294	0.226	-0.672
2%-2 mm	0.691	0.057	-0.213	-0.048	-0.472
Spleen	$D_{98\%}$	$D_{2\%}$	D_{mean}	PRV D_{max}	
3%-3 mm	-0.131	0.135	0.248	-0.624	
2%-2 mm	0.249	0.578	0.378	**-0.777**	

ArchCHECK®

r					
	PTV			OAR	
Prostate	$D_{98\%}$	$D_{2\%}$	D_{mean}	Rectum $D_{50\%}$	Rectum $D_{5\%}$
3%-3 mm	0.059	0.651	0.609	**0.900**	0.502
2%-2 mm	0.283	**0.779**	**0.773**	**0.806**	0.294
PBI	$D_{98\%}$	$D_{2\%}$	D_{mean}	Lung $D_{40\%}$	Lung $D_{10\%}$
3%-3 mm	0.092	**0.813**	**0.949**	0.628	-0.332
2%-2 mm	0.238	**0.892**	**0.987**	0.649	-0.427
Spleen	$D_{98\%}$	$D_{2\%}$	D_{mean}	PRV D_{max}	
3%-3 mm	0.576	0.414	**0.874**	0.519	
2%-2 mm	**0.767**	0.687	**0.983**	0.323	

Conclusion: The results showed a different sensitivity to errors for the two systems, in particular in the case of ring and gantry rotations. This variation can be related to the different dose reconstruction methods applied: ArcCHECK® uses both the entry and exit dose, while OCTAVIUS® system the planar dose measured by the inserted detector and the PDD of the beam. Furthermore, no significant correlation was found between the results of the 3D γ analysis and the DVHs variations due to the intentional errors, as shown in literature.

PO-0822

Tumor margin estimation by multiple Bragg peak detection in carbon ion therapy

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